Various-scale controls of complex subduction dynamics on magmatic-hydrothermal processes in eastern Mediterranean

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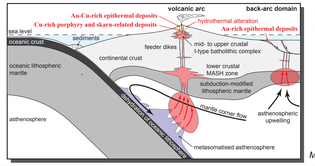
Introduction

Ore deposits and related magmatism in subduction and post-subduction environments are controlled by the thermal structure and hydrous and magmatic fluid dynamics from the underlying mantle to the upper crust.



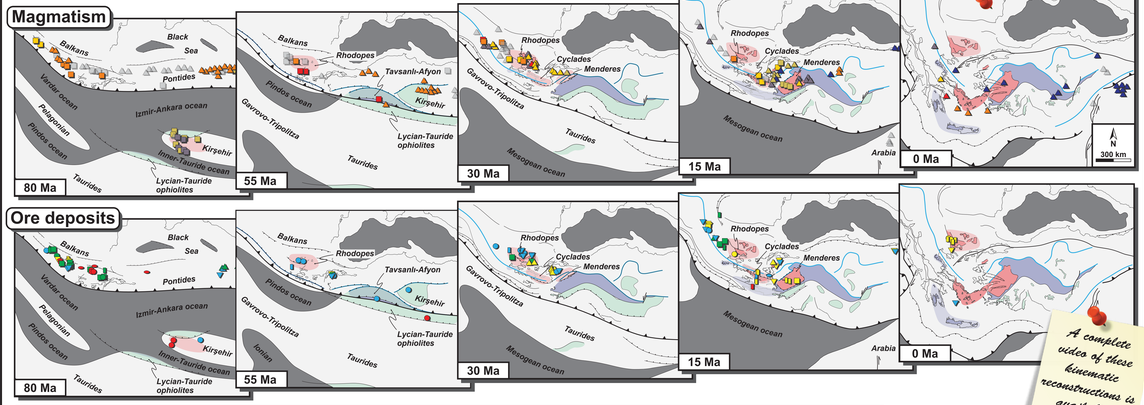
In regions where the **3D subduction dynamics is complex** such as in eastern Mediterranean,

- **Which processes affect the distribution of mineralization and magmatism?**
- **Considering this evolution at different scales, can we better constrain the dynamics of subduction in eastern Mediterranean?**

Modified from Richards, 2011

Ore deposits in subduction environment
- 55 % of the metal production in Cu
- 16 % of the metal production in Au
Major economic interest!

Large-scale evolution: input from kinematic reconstructions



A complete video of these kinematic reconstructions is available!

Petrological affinity
- continental crust
- oceanic crust
- obducted oceanic crust

Metamorphic Core Complex (MCC)
- buried/exhumed high pressure MCC
- buried/exhumed high temperature MCC

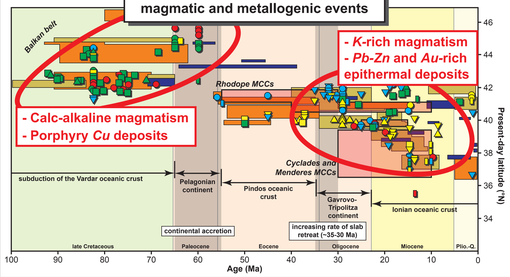
Tectonic structures
- active major thrust fault
- active major high-angle normal fault
- active major low-angle normal fault
- active major strike-slip fault
- inactive major fault
- major oceanic suture

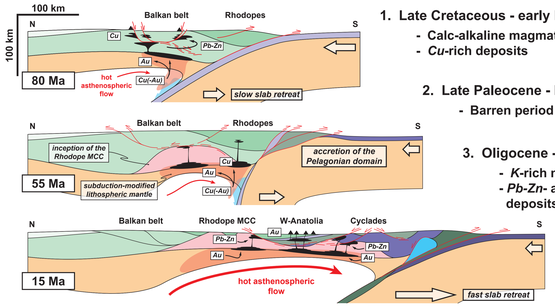
Magmatism
- volcanism/plutonism (v./p.)
- alkaline v./p.
- shoshonitic v./p.
- high-K calc-alkaline to shoshonitic v./p.
- high-K calc-alkaline v./p.
- medium- to high-K calc-alkaline v./p.
- medium-K calc-alkaline v./p.

Ore deposits		metal content			
		Cu	Au	Pb-Zn	Fe
deposit type	porphyry	■	■	—	—
	skarn	■	■	■	■
	high-sulphidation epithermal	■	■	—	—
	low-sulphidation epithermal	—	■	■	—
	fault-related	■	■	■	■
	volcano-sedimentary	—	—	■	■

3 main periods in eastern Mediterranean with a general southward migration of the magmatic-hydrothermal systems

Latitude versus age diagram from the magmatic and metallogenic events

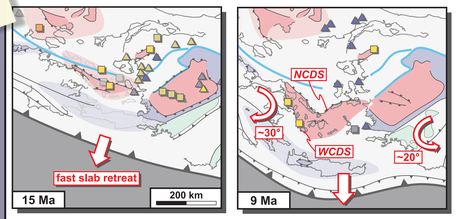




1. **Late Cretaceous - early Paleocene**
   - **Calc-alkaline magmatism**
   - ***Cu*-rich deposits**
2. **Late Paleocene - Eocene**
   - **Barren period**
3. **Oligocene - Neogene**
   - ***K*-rich magmatism**
   - ***Pb-Zn*- and *Au*-rich deposits**

Small-scale evolution: the Miocene geodynamics of the Aegean and western Anatolia

Since 35-30 Ma, fast slab retreat resulted in the opening of the Aegean back-arc domain. However, 15 Ma ago, a major change occurred in the dynamics of this back-arc opening.



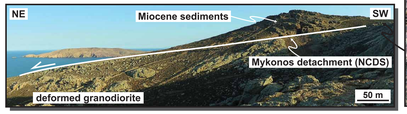
Field evidences

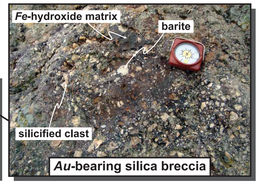
- **Block rotations**
  [van Hinsbergen et al., 2005]
- **Appearance and westward migration of alkaline volcanism**
  [Dilek & Altunkaynak, 2009]
- **Westward migration of plutonism** from the Menderes to Cyclades with an **increase of the mantle component**
  [Altherr & Siebel, 2002]

In the Cyclades, the **activity of large-scale detachment systems** such as the *North Cycladic Detachment System* (*NCDS*) and the *West Cycladic Detachment System* (*WCDS*) is **contemporaneous with the emplacement of magmatic intrusions and ore deposits**

Mykonos island

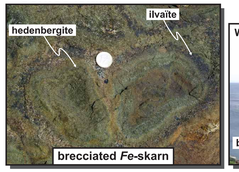
- Syn-extensional granodiorite below the NCDS
- *Au*-bearing silica breccia and base metal-barite veins

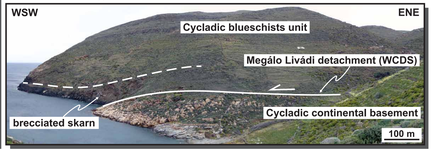




Serifos island

- Syn-extensional granodiorite below the WCDS
- *Fe*-rich high temperature and medium temperature skarns

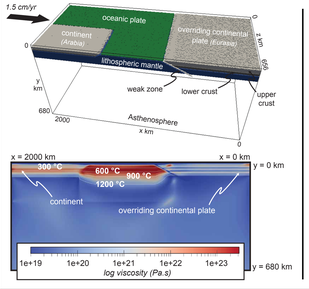


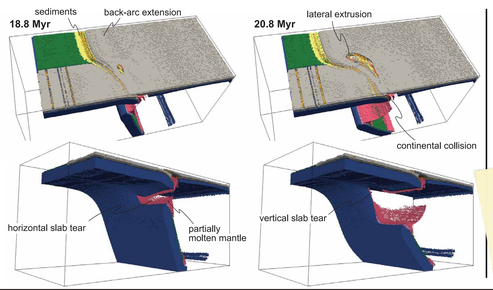


Combined scales: numerical modeling of subduction dynamics

Using a simple large-scale model of subduction, can we reproduce these geological observations and relate them to the subduction dynamics and associated mantle flow?

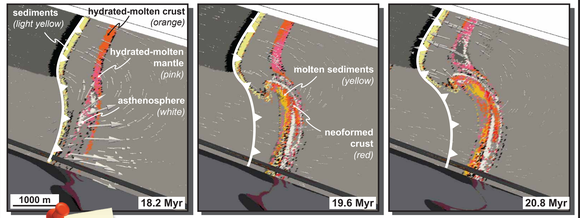
3D thermo-mechanical numerical modeling with complex rheologies, integrating fluid/melt transport, partial melting and melt extraction mechanisms *[Gerya & Yuen, 2003]*





Videos of this model are also available!

25 km-depth horizontal cross-sections (base of stretched crust)



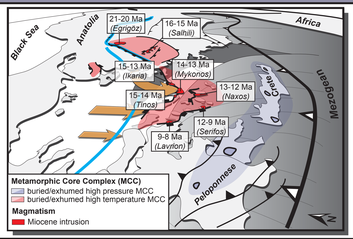
Lateral migration of magmatism and asthenospheric upwelling related to toroidal flow

In back-arc region, increase of mantle-derived material relative to crustal-derived material

Conclusion

In eastern Mediterranean region, a southward migration of magmatic-hydrothermal systems is observed from the late Cretaceous to nowadays

- **Barren periods** are associated to **dominant compressional or transpressional tectonics** within the upper plate (e.g. continental accretion)
- ***Cu*-rich periods** are related to **stagnant magmatic arc** resulting from the **dehydration of the subducted oceanic crust** and the **partial melting of the mantle wedge**
- ***Au*-rich periods** are related to **fast slab retreat and associated mantle flow** inducing the **partial melting of the lithospheric mantle or the base of the crust where Au was previously stored**



During the Miocene, a secondary westward migration of the magmatic-hydrothermal activity is observed from the Menderes massif to the Cyclades

- **Possible consequence of a slab tearing event below western Anatolia and related hot asthenospheric flow**

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